Orbitally paced Silurian glaciations invoke negative weathering feedbacks that reverse global cooling

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Chemical weathering of continental rocks regulates atmospheric CO_2 and therefore global climate (Berner et al., 1983). On geological timescales, silicate weathering leads to drawdown of atmospheric CO_2, while oxidative weathering of ancient sedimentary organic matter and/or pyrite leads to a release of CO_2 to the atmosphere (Berner, 2006). Chemical weathering shows a complex dependence on climatic parameters such as temperature, precipitation, physical weathering and ice cover (Anderson et al., 1997; Riebe et al., 2004;). However, the response of chemical weathering to climatic change induced by orbitally paced changes in insolation is not well understood.

The Silurian was punctuated by four large (> 5 ‰) positive carbon isotope excursions from the early Wenlock through to the Silurian-Devonian boundary, often associated with positive oxygen isotope excursions, extinction events and lithological changes (Calner, 2008). It has been postulated that these events could have been driven by periodic glacial expansions over Gondwana, induced by a reduction in insolation related to the ~2.4 Myr modulation of the eccentricity record (Cherns et al., 2013). Moreover, high resolution stratigraphic records for the Hirnantian, a major glacial event just prior to the Silurian, suggest multiple glacial maxima paced by obliquity insolation minima (Ghienne et al., 2014). The Silurian therefore provides a useful time period to study the response of potential climate stabilising weathering feedbacks to orbital forcing on both short (10^5 years) and long (10^6 years) timescales.

Organic-rich shales and carbonates respectively record the osmium and lithium isotopic composition of seawater and have provided unparalleled information concerning the weathering response to climatic and geological events, and the long-term control of atmospheric CO_2 (Georg et al., 2013; Misra and Froelich, 2012). Here, we present the Os and Li isotope records of marine sedimentary rocks that span four Silurian glaciations. Using a coupled osmium-lithium-carbon model, we show that variations in insolation related to the ~2.4 Myr eccentricity modulation led to extensive glaciation events every ~4.8 ±0.8 Myr. Each of these glacial periods is characterised by two glacial maxima paced by the 405 kyr eccentricity cycle. Global cooling and the expansion of continental ice reduced silicate weathering rates, while enhancing the oxidative weathering of organic and/or sulphide rich shales. This led to a net flux of CO_2 to the atmosphere, reversing global cooling, and thereby helping maintain a habitable planet.

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